CHAPTER 10
Current Status of Aquaculture in the United States

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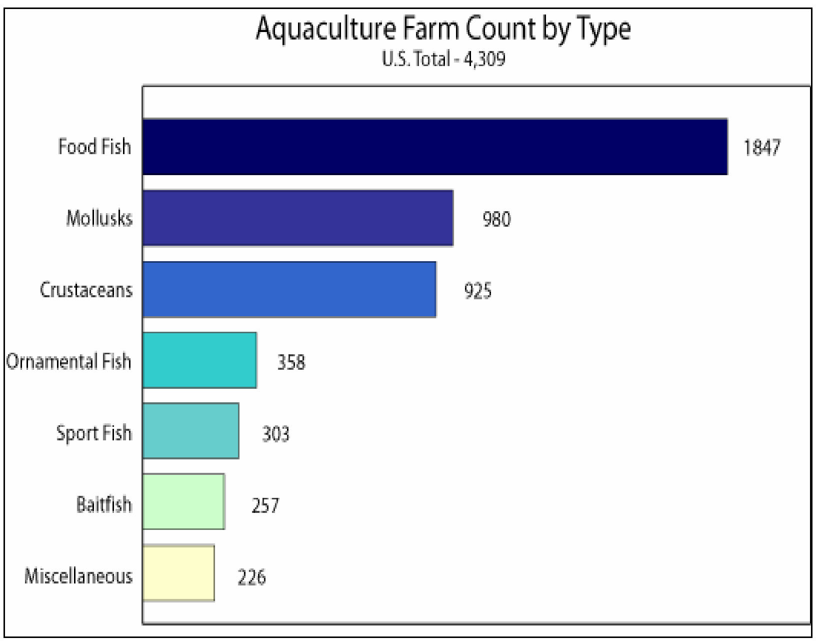
This chapter outlines the current variety of species, technologies, methods, and places associated with aquaculture in the United States. The chapter focuses on six major species groups (catfish, salmon, shellfish, trout, tilapia, and public sector stocking) to illustrate the breadth of aquaculture activities.

U.S. aquaculture scope and diversity

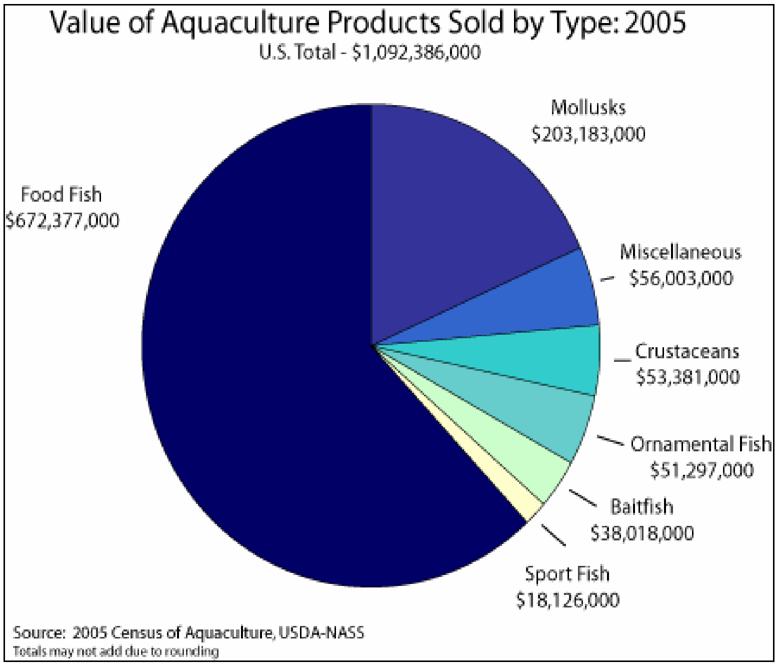
Private sector aquaculture in the United States is diverse, vibrant, and technically innovative, though production falls far short of what is needed by the Nation's markets. Aquatic farmers grow a wide variety of fish and shellfish species in fresh and salt water and do so in all regions of the country. This is illustrated in Figures 10.1 to 10.4 and Table 10.1 below.

Figure 10.1. Aquaculture farm count by type.



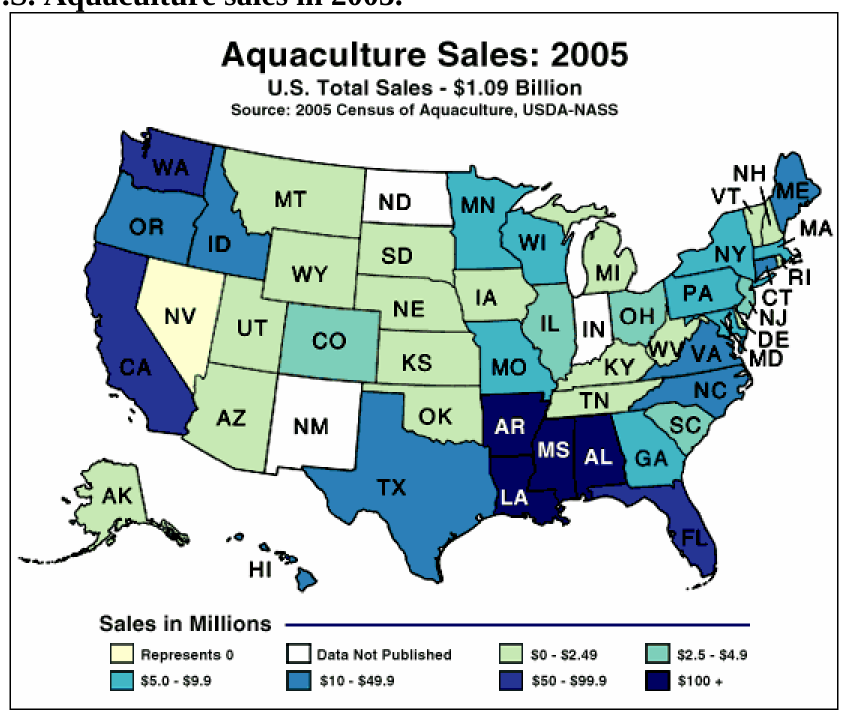
Source: United States Department of Agriculture

Figure 10.2. Value of aquaculture products sold by type in 2005.



Source: United States Department of Agriculture

Figure 10.3. U.S. Aquaculture sales in 2005.



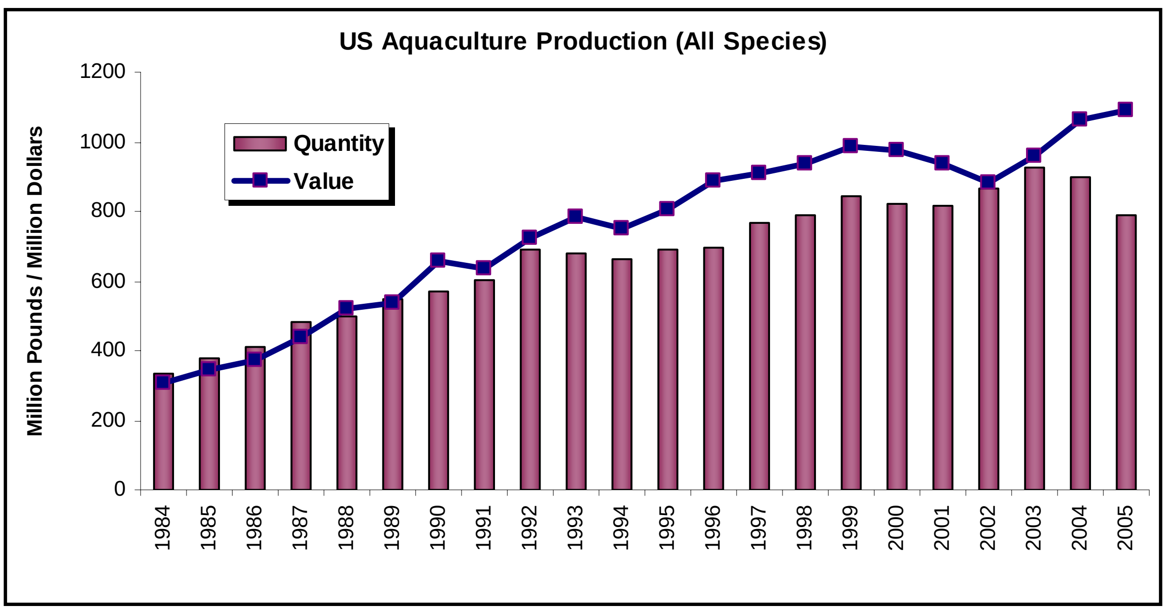
Source: United States Department of Agriculture

Table 10.1. Aquaculture Statistics to show the weight of production of different categories in 2005.

Species	Thousand pounds	Metric tons	Thousand dollars
Finfish			
Baitfish	NA	NA	38,018
Catfish	607,933	275,757	429,245
Salmon	20,726	9,401	37,439
Striped bass	10,970	4,976	27,655
Tilapia	17,203	7,803	29,620
Trout	60,636	27,504	65,469
Shellfish:			
Clams	12,564	5,699	72,783
Crawfish	35,933	16,299	21,143
Mussels	962	436	4,990
Oysters	13,711	6,219	92,602
Shrimp	8,037	3,646	18,684
Miscellaneous	NA	NA	254,738
Totals	**788,675**	**357,741**	**1,092,386**

Source NMFS, 2007

Figure 10.4. Growth of the U.S. aquaculture industry.



Source: NMFS, 2007

Aquaculture for food is by far the dominant sector of the industry. If production of those products sold for food, namely food fish, mollusks and crustaceans are added together, their total value in 2005 was $929 million, 85% of all private sector aquaculture. This does not imply that other sectors are not important. Ornamental fish aquaculture, for example, provides the added value of relieving pressure on natural fish populations that might otherwise be targeted for this trade. The economic multiplier that might be applied to a kilo of sport fish for recreational stocking is almost certainly higher than that applicable to a kilo of food fish; and this industry also helps to relieve pressure on natural populations. In fact, conservation aquaculture for replenishment and restoration of wild fish populations is a branch of the business that may see substantial expansion in the years ahead.

However, there is another part of the national aquaculture effort that is not represented in these figures. This is public sector hatchery production, which includes federal, state, tribal and private non profit hatcheries for species such as salmon, trout, bass, crappie and other recreational fish and which are to be found in all parts of the country. These hatcheries produce juveniles for stocking public fresh and marine waters contributing substantially to the Nation's commercial and recreational seafood harvest and representing a large investment in aquaculture facilities. For example, there are almost 400 salmon hatcheries on the West Coast that release about 1.7 billion juvenile salmon per year into the Pacific Ocean,[1] which, once they return as adults, support commercial and recreational fisheries throughout the region.

In this respect, aquaculture is different from most other business activities in the U.S. in that there is a large public as well as a private sector. Statistics on the overall scope, production and value of this public sector have not been the subject of a census as they have in private aquaculture, but this does not mean that public aquaculture is not important or that it should be omitted from a general overview of the US aquaculture industry. Hatcheries use exactly the same methods as are used in private aquaculture and, importantly, also use resources of water and land that might otherwise be available for private aquaculture development. Thus, details about their scope and contribution to the national aquaculture effort are included in section 6 below.

Farming of the principal species and species groups in the United States

To provide an overview of the breadth and diversity of methods used in aquaculture, descriptions are given below of the farming of each of the top species or species groups in the U.S. Each of them uses different methods of production and therefore these descriptions provide a good general overview of the nature and scope of the entire industry. They include:

1. Channel catfish – farmed in ponds
2. Atlantic salmon – farmed in floating net pens
3. Bivalve shellfish (oysters, clams and mussels) – mostly farmed in littoral or shallow sub-littoral areas
4. Rainbow trout – farmed in flowing fresh water in raceways or tanks
5. Tilapia – farmed in recirculating aquaculture systems (RAS)
6. Public sector aquaculture

1. Pond farming of Channel catfish

Catfish are farmed almost entirely in structured ponds filled by water pumped from aquifers or by natural runoff. Several other species such as shrimp, crawfish and baitfish are also farmed in the same way but catfish production is by far the dominant activity in the United States and is therefore the focus of this description.

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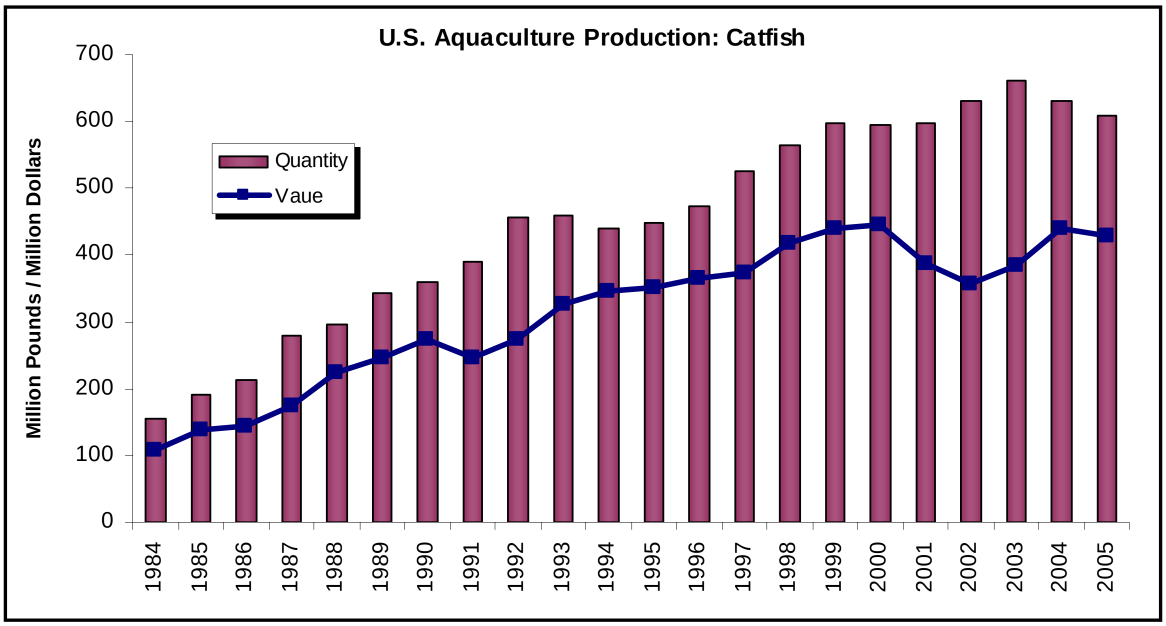
[1] White (2005 gives a figure of 1.4 billion for Alaska. Bartlett (2006) gives a figure of 300,000 for hatcheries in Washington. Oregon and California.

Almost all catfish production in the United States is located in southern states, where the climate provides adequate water temperatures for growth, and where the soil and elevation are suitable for pond construction (Figure 10.6). Harvey (2006) reported over 170,000 acres of ponds were operating in the country in March 2006. Much of this area was farmland, converted when landowners and farmers decided that catfish production would be more profitable than traditional agricultural crops. According to Tucker et al. (2004), this combination of climate, soils, available farmland, willing farmers, and the availability of a species of fish well-suited to farming represents a complex of conditions not easily replicated.

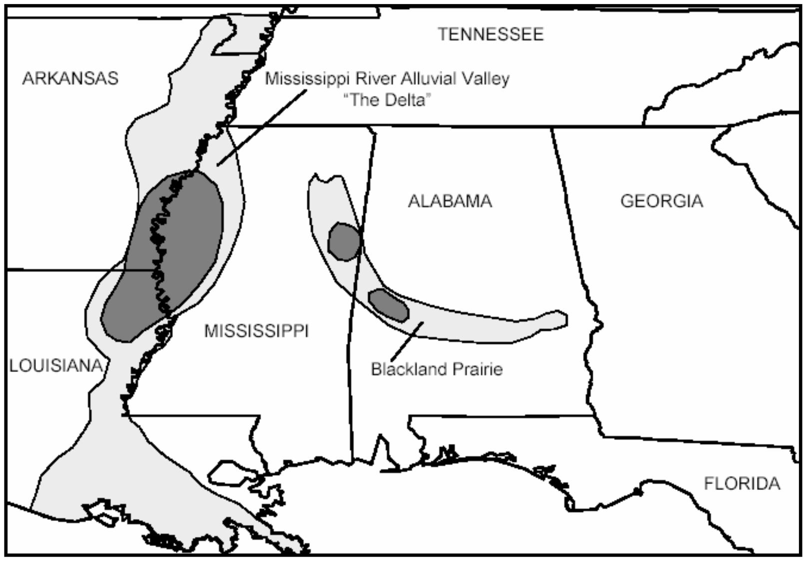
Channel catfish farming developed rapidly from 1980 to 2003 (Figure 10.5) and has become the largest sector of the national aquaculture industry. The basis for this growth involved complex interactions between biology, sociology, and economics, which all came together in the South Central and Southeast part of the US (Tucker et al., 2004).

Figure 10.5. U.S. farmed catfish production and value.



Source: NMFS, 2007

Figure 10.6. Major U.S. catfish farming areas.



Source: Tucker et al., 2004

Catfish farming has had a major economic impact on those areas in which it is practiced (Box 10.1). With capital investment of $642 million, the catfish farming industry in Mississippi employs over 7,000 people in jobs directly related to production (Dean and Hanson 2003). Further, by using locally produced agricultural raw materials as ingredients in feed, catfish farmers add value to national agricultural commodities in the same way that producers of poultry, hogs, and beef add value. Catfish production has declined substantially during the past four years due to increased production costs (feed and fuel) and competition from catfish substitute species from Asia. 2008 U.S. catfish production is projected to be between 470 - 480 million pounds, down from a high of 630 million pounds in 2004 (NMFS 2007, Haley, 2008).

In recent years U.S. catfish farmers have experienced fierce competition from overseas fish farmers that produce fish similar to catfish, mostly "basa", farmed in Vietnam and Tilapia, which is farmed in many tropical and sub-tropical countries. According to Harvey (2006), pond acreages have declined for four years in a row and, although there is potential to increase capacity, imports of competing products have held prices in check, while the cost of production has increased steadily with inflation and rising costs of feed. Recent trends in catfish processing volumes and prices are shown in Figure 10.7 while historical trends in production cost versus price are shown in Figure 10.8.

Box 10.1. Summary of catfish industry facts.

Catfish Facts

- Mississippi farmers sold 381 million pounds of farm-raised catfish to processing plants in 2001. This was around 64 percent of the total farm-raised catfish processed in the United States.
- There are more than 111,000 acres of catfish ponds in Mississippi. This is 177 square miles of ponds. If this were one pond, it would be a mile wide, and stretch along I-20 from the Alabama-Mississippi border to the Mississippi River.
- Mississippi catfish were fed more than 950 million pounds of feed in 2001. This could be hauled in a train of 4,950 96-ton hopper cars or a caravan of 19,800 18-wheel 24-ton feed trucks. At least 4 acres of grain crops are needed to support one foodsize fish acre.
- As shown in the table below, the Mississippi catfish industry employs more than 3,000 people on catfish farms, more than 3,600 workers in processing plants, and 330 in feed mills. Total payroll exceeds$102 million, and total industry investments exceed $600 million.
- The modern catfish industry originated in the Mississippi Delta in the late 1960's and early 1970's by farmers who were seeking an alternative to low-priced tow crops on clay-based soils.
- Mississippi's farm-raised catfish industry is a model world-class commercial aquaculture industry that is profitable, sustainable, and environmentally sound.

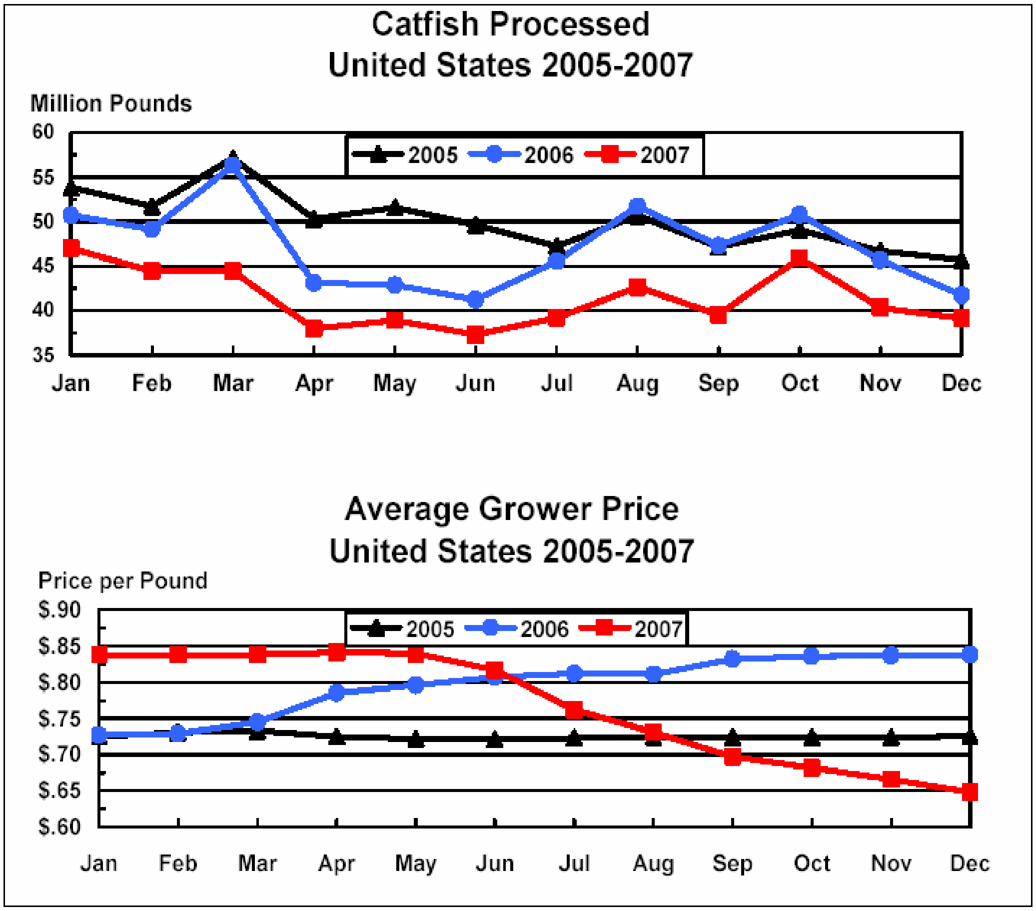
Direct Impact of the Catfish Industry in Mississippi

Sector	Number of jobs	Payroll $(Millions)	Sector Revenues* $(Millions)	Investments $(Millions)
Feed	330	8	150	95
Farming	3,000	37	260	397
Processing	3,671	57	435	200
Total	7,001	102	845	642

* includes payroll from payroll column.

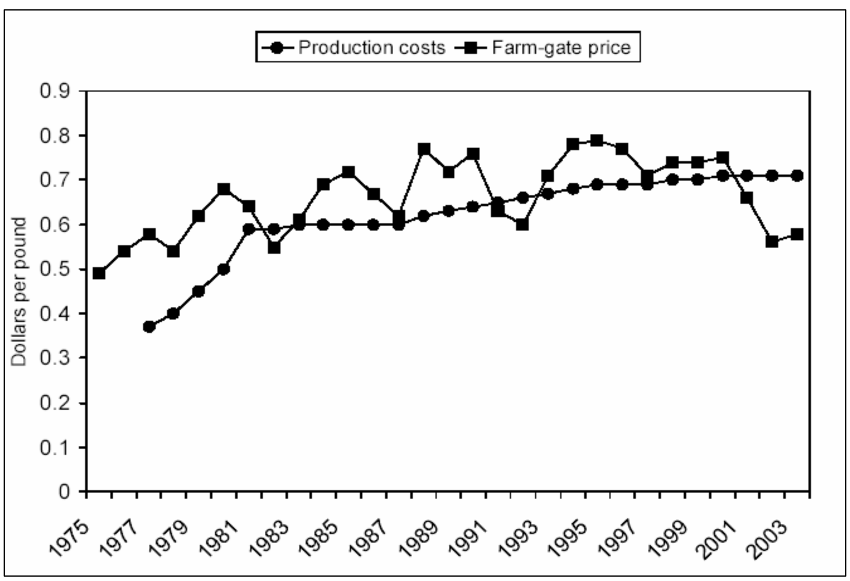
Source: Dean and Hanson, 2003

Figure 10.7. Amount processed and average grower price of catfish in the United States, 2005-2007.



Source: NASS, 2008.

Figure 10.8. Cost of production and farm gate price for catfish to illustrate the cyclical nature of the industry.



Source: Tucker et al., 2004

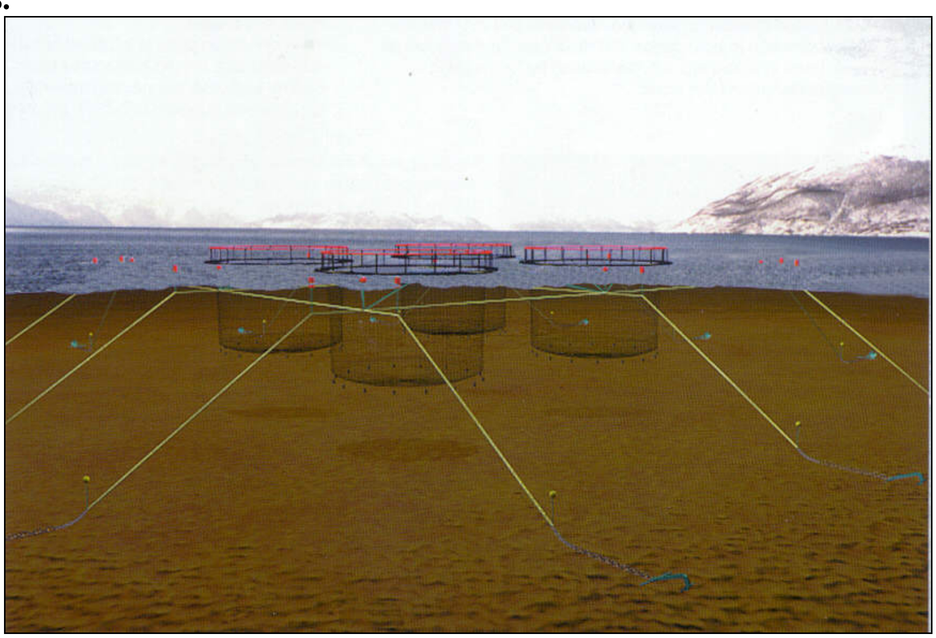
2. Net pen farming of Atlantic salmon

Salmon are farmed commercially in only two areas of the U.S.: Maine and Washington. The industries in these states represent less than 2% of a much larger global business that has developed quickly in the last 20 years. Global production of farmed Atlantic salmon in 2007 is estimated to have been 1.4 million mt of which the US imported about 300,000 mt (Seafood Intelligence, 2008).

Salmon are farmed in a two-stage process. First is the production of juvenile salmon, called 'smolts', in fresh water hatcheries. Second is the grow-out of these fish to market size in seawater cages or net pens. The freshwater stage is similar in many respects to the farming of rainbow trout and production of salmon juveniles for enhancement (Section 6 of this chapter). The hatcheries employ a flowing water culture method using raceways, or circular tanks, to raise newly hatched salmon 'alevins' through the early part of their life until they are ready as smolts to go to saltwater. The source of water can be a lake, stream, spring, or well with typical flows required being in the order of two to five million gallons per day.

The operating principle of net-pen farming is that net-pen containers, or cages, are suspended from floating collars and held in shape by weights attached to the bottom of the net (Figure 10.9). Water exchange then occurs within the net pen due to tide and wind driven water currents. The principle can be applied to many species of marine fish and other species that are grown in net pens in the United States, but on a much lesser scale than Atlantic salmon, including Pacific threadfin, white sea bass and yellowtail jack.

Figure 10.9. Diagram of a simple net pen that can be used for salmon and many other fish species.



Atlantic salmon have been farmed in Maine and Washington since the mid-1980s after attempts to farm Pacific Coho salmon in Washington during the 1970s and early 1980s came to an end. At that time, it was realized that Atlantic salmon were more suitable for farming because they are relatively easy to handle, grow well under culture conditions, have a relatively high commercial value and adapt well to farming conditions outside their native range (Knapp et al, 2007).

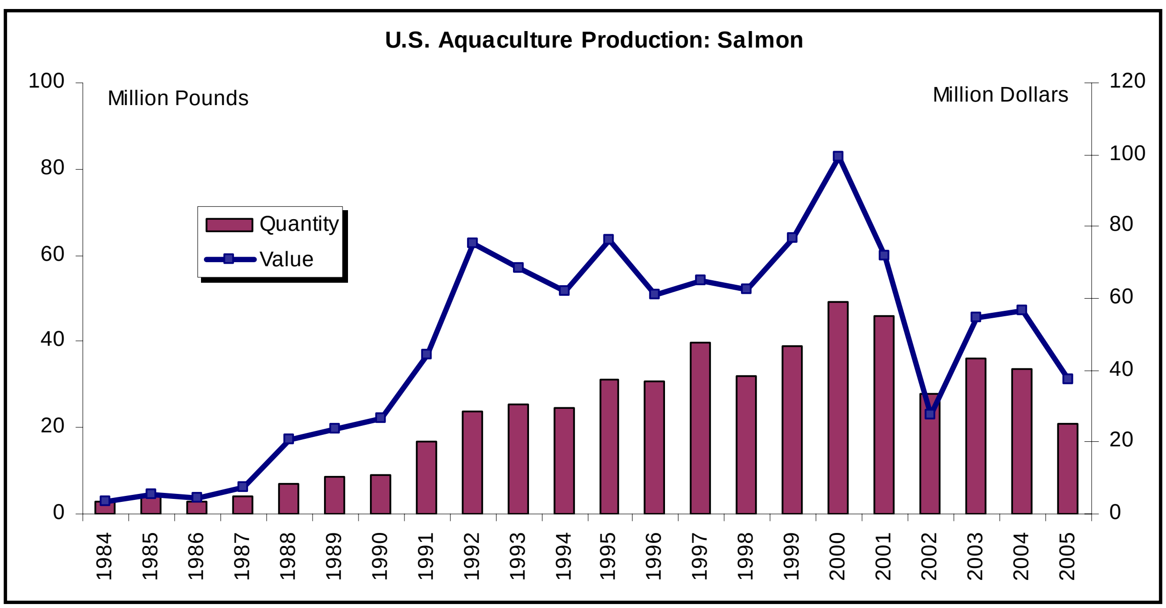
In 2005 (see Table 10.2), total US production of Atlantic salmon was 9,401 metric tons, with a value of $37.4 million. However, as shown in Table 10.2 and Figure 10.10, both production and value were higher in previous years. These changes are due in part to globally driven swings in farmed salmon prices, 2002 being a particularly difficult year (Table 10.2), and in part to the fact that the industry in Maine suffered from the disease Infectious Salmon Anemia (ISA) between 2001 -2003. Even though ISA is now largely controlled, it still limits overall production volume.

Table 10.2. Production and sales of US farmed salmon 2000 – 2005.

Year	MT produced (x1,000)	Sales	Av price per kg
2000	22,395	99,208	$4.43
2001	20,769	72,019	$3.47
2002	12,734	27,756	$2.18
2003	16,315	54,706	$3.35
2004	15,157	56,679	$3.74
2005	9,401	37,439	$3.98

Source: NMFS 2006

Figure 10.10. U.S.-farmed salmon production.



Source: NMFS, 1999, 2003, 2007

3. Oysters and Clams

Farming of bivalve mollusks in the United States is dominated by the production of several different species of oysters and clams (Table 10.3). Two of the most important species, namely *Crassostrea gigas* and *Tapes philippinarum*, are not native to the United States but came originally from Asia. Other cultivated shellfish include mussels, scallops, and geoducks.

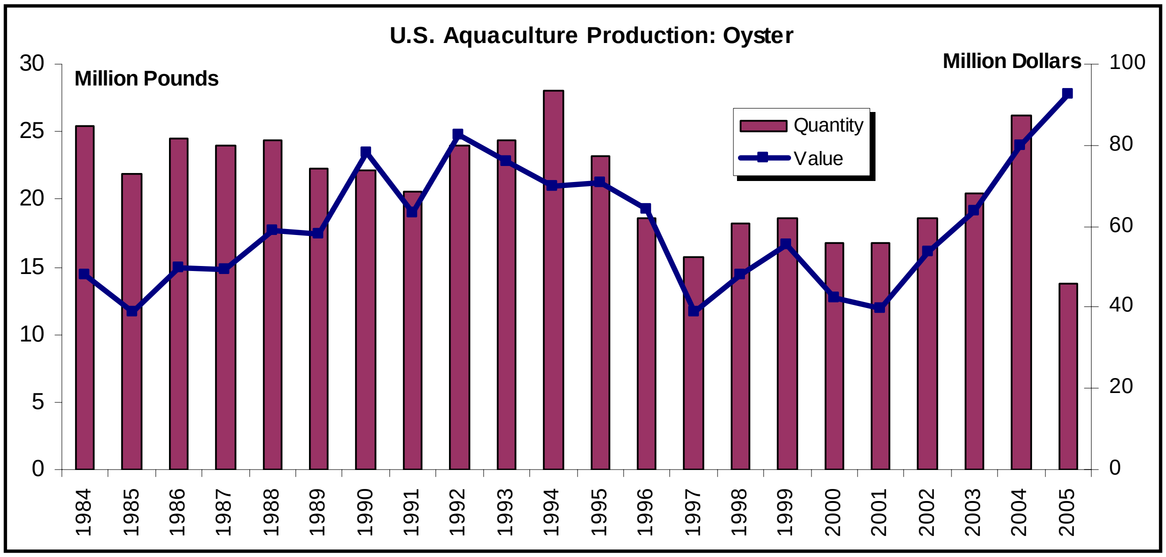
Annual data for the production of oysters and clams from 1984 to 2005 (Figure 10.11) show a combined production total of 26.3 million lbs. meat weight (12.6 million lbs of clams and 13.7 million lbs of oysters) that had a first sale value of $165.4 million ($72.8 million of clams and $92.6 million of oysters). Thus, another feature of the successful bivalve farming industry is the high unit value of its products. As demonstrated here, the average value is $6.3/lb meat weight.

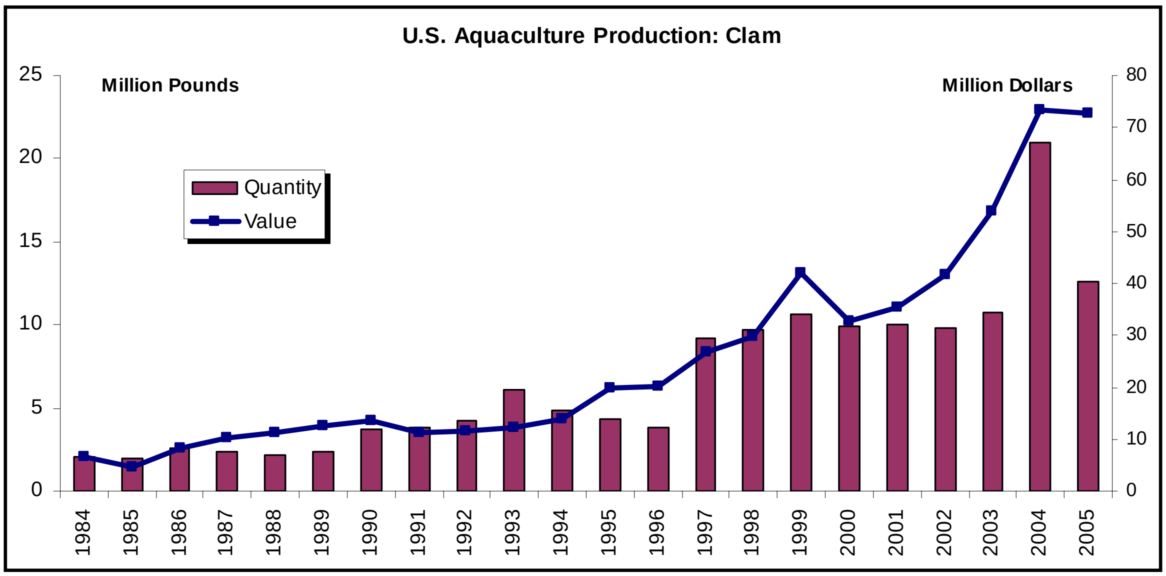
The methods used for bivalve aquaculture differ from other forms of aquaculture because no food is added to the culture water during the grow-out phase. The shellfish are grown out mostly in protected coastal waters (see Figure 10.12) and feed by filtering large volumes of seawater through their gills to extract the natural phytoplankton (microscopic algae) that are in it. Depending on the species, size, water temperature, and other variables, the volume of water filtered by each animal can be 20 to 80 gallons per day. During nursery and grow-out stages, this demand for water (and associated phytoplankton) and physical space necessitate that it be done in the natural environment. It is neither practical nor economical to culture most shellfish to maturity, which typically takes two to five years, in land-based systems (Kramer et al., 2000).

Table 10.3. Commercial (farmed and wild) oysters and clams of the U.S.

Oysters	**Scientific name**
Pacific oyster	*Crassostrea gigas*
Olympia oyster	*Ostreola conchaphila*
European oyster	*Ostrea edulis*
Kumomoto oyster	*Crassostrea sikamea*
Eastern oysters	*Crassostrea virginica*
Clams	
Quahog (hard)	*Mercenaria mercenaria*
Manila (Pacific)	*Tapes philippinarum*
Ocean quahog	*Arctica islandica*
Softshell	*Mya arenaria*
Surf (Atlantic)	*Spisula solidissima*
Geoduck	*Panope abrupta*

Figure 10.11. U.S.-farmed oyster and clam production.

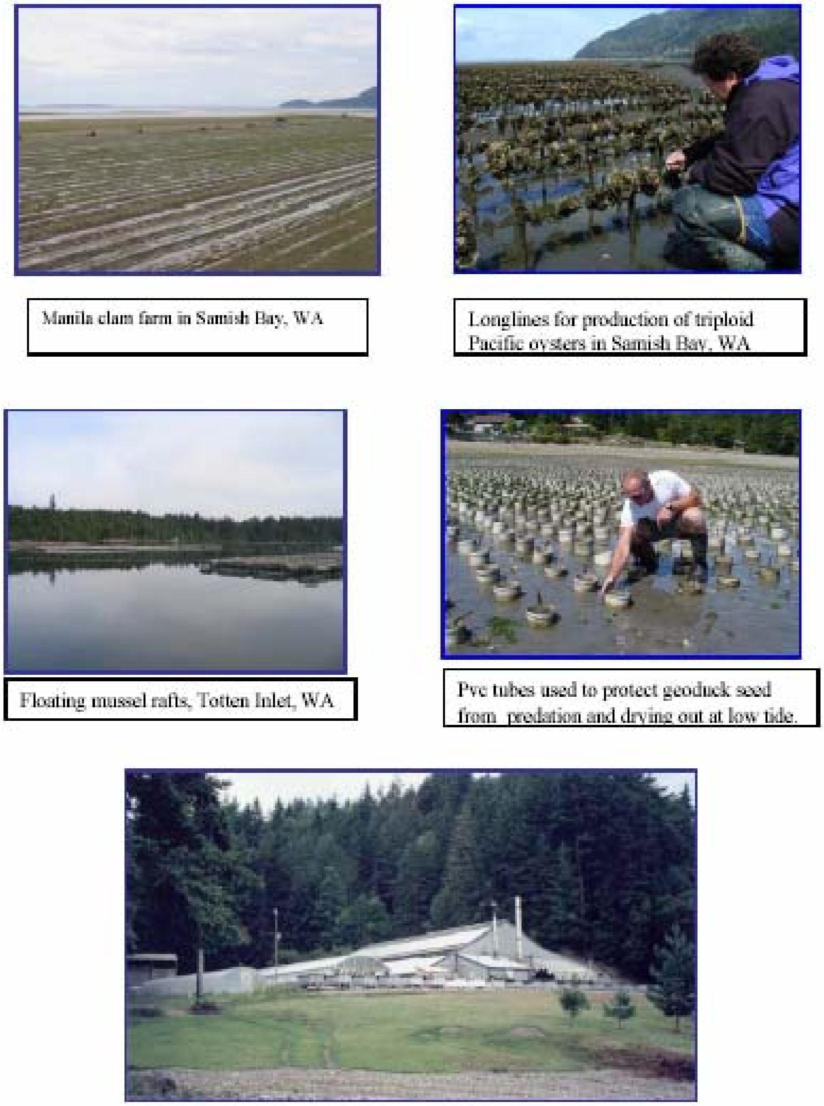




Source: NMFS, 1999, 2003, 2007

This dependence on filtering natural food puts a high premium on the need for clean water for shellfish farming, especially for species such as oysters which are eaten raw. Harvesting closures, due to the presence of potentially harmful bacteria, viruses, and other contaminants, are quite common in shellfish farming, while the industry itself has been and continues to be a strong advocate for clean water. There are, in fact, many cases where the presence of shellfish helps to improve water quality by filtering out particulate matter. For example, Newell (1988) estimated that, prior to 1870; the oyster populations in the Chesapeake Bay were capable in the summer of filtering the entire volume of water in the estuary in three to six days. With reduced stocks of oysters, such filtering is now estimated to be in the order of 300 days, and this may be a contributing factor to the degraded water quality in the Chesapeake Bay today.

Figure 10.12. Shellfish farms in Washington State.



Manila clam farm in Samish Bay, WA

Longlines for production of triploid Pacific oysters in Samish Bay, WA

Floating mussel rafts, Totten Inlet, WA

Pvc tubes used to protect geoduck seed from predation and drying out at low tide.

Taylor United's shellfish hatchery at Dabob Bay, WA

Source: Bill Dewey, Taylor Shellfish Farms

Bivalve farming occurs to a greater or lesser extent in every coastal state in the country. Underlying all methods of farming are the basic principles of securing and protecting a stock of shellfish in bodies of clean water from which they can feed, while allowing access to farmers for general care and harvesting. Thus, oysters can be grown on the bottom or in racks and trays, or in the water column using longlines (Figure 10.13), bags strung on lines, or wrapped on pilings (bouchout). Clams, on the other hand, because of their need to dig into the substrate, are almost always grown on the bottom, and are often covered with plastic mesh to protect them from predators.

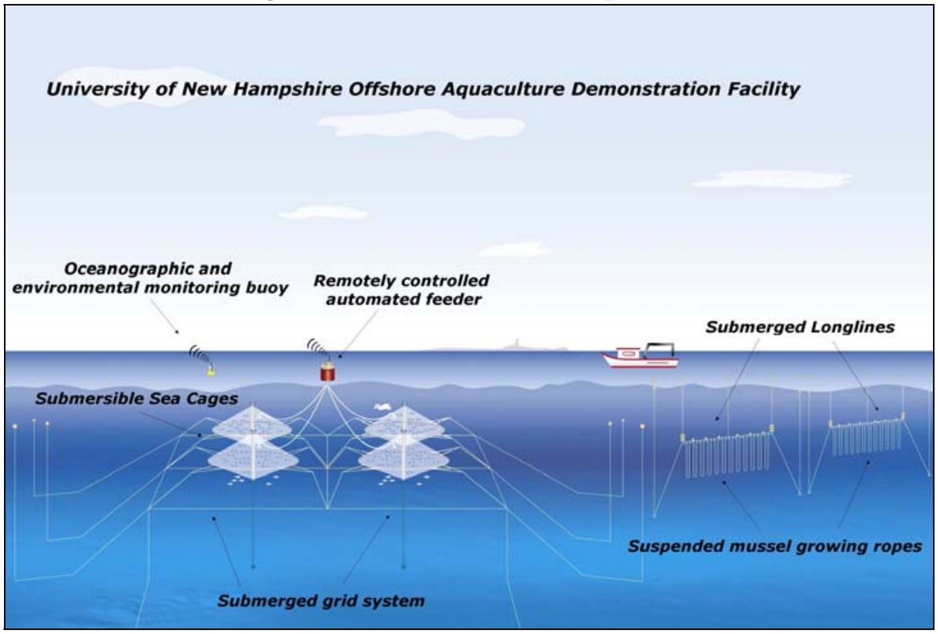
One difficulty of interpreting production numbers and describing the shellfish farming industry is that shellfish aquaculture activities vary widely. Therefore, determining what actually constitutes aquaculture is a challenge. On one side of the spectrum are managed wild fisheries that rely upon natural recruitment to re-seed public beds. Fishermen (and recreational harvesters) get licenses to harvest the wild resource. On the other side is the intensive cultivation of privately-owned tidelands. Beds are seeded with juveniles that began as larvae in a hatchery and are then reared for a period of time in an upland nursery before being planted in some sort of grow-out system. In between these extremes are many other situations, with varying levels of control over the source of the seed stock and the method by which it is grown to market size (Kramer et al., 2000). Difficulties with regard to definition notwithstanding, all U.S. shellfish production is limited by a lack of access to tidelands and coastal waters. Competition for these resources, and pollution in some areas, make expansion difficult. Therefore, industry growth in recent years has been slow, despite the fact that technologies for farming most species are well established and market demand for industry products is strong.

One example of the growth that can occur when tidelands and near-shore coastal waters are made available is the culturing of hard clams in Florida. This began in the early 1990s, primarily through job re-training efforts designed for displaced workers in the commercial fishing industry. By 2003, there were 237 clam farms with annual combined sales of $13 million (Table 10.4). In turn, these farms supported the activity of hatcheries and land-based nurseries throughout the state while certified shellfish wholesalers in the state purchased the clams and distributed them throughout the nation. An analysis by Philippakos et al. (2001) assessed the aggregate economic impact of this industry at $34 million. However, hurricanes in 2004 and 2005 caused severe damage to this industry so that by 2005 there were only 153 farms and sales fell to $9.8 billion with an average price per clam sold of 10.8 cents (Table 10.4 and NASS 2006). There were 20 operations raising clam seed.

Similar loss of growing capacity occurred in the Gulf States' fisheries for oysters, clams, and mussels was caused by Hurricane Katrina in August 2005. The Gulf Oyster Task Force estimated the cost to restore oyster beds and infrastructure over the entire affected area to be more than $400 million, while the Gulf Oyster Industry Council estimated it to be more than $335 million (Buck, 2005). When it occurs, restoration will most likely happen with the help of hatchery-produced seed to stock otherwise un-tended public oyster beds. This is an example of how public and /or private hatcheries can serve as an important tool in fishery management.

The outlook for the national oyster and clam production is for only modest growth as has occurred, for example, in Washington over the past 30 years, where losses of capacity due to closures or downgrades in water quality have been offset by developments in farming technology. Growth, if it is to occur, will have to include advances in hatchery production as well as new, on-growing methods that both exclude predators more efficiently and facilitate production in areas not previously developed (Dewey, 2006).

Figure 10.13. Offshore farming of mussels in New Hampshire.



Source: University of New Hampshire Atlantic Marine Aquaculture Center

Table 10.4 Clam farm sales and clam seed planted in Florida during 2005.

Year	Farms	Farms With Sales	Clams Sold (Millions)	Sales (Millions)
2003	237	192	134.0	$13.0
2005	153	142	92.1	9.8
			Seed Planted	
2002			289,791,000	
2003			350,398,000	
2004			392,100,000	
2005 (estimated)			350,000,000	
2006 (expected plantings)			500,000,000	

Source NASS 2006

However, one shellfish farming sector that might see more rapid growth is the offshore culture of species such as mussels and scallops that can be grown in suspended culture, i.e. on ropes or in special net containers suspended from floating rafts (Figure 10.13). Should these methods, now being developed at the University of New Hampshire, become widely practiced it could change the present mix of production that characterizes the nation's shellfish farming industry today (Anon 2007).

4. Rainbow trout

Hinshaw et al. (2004), in their review of farming the rainbow trout (*Onchorhynchus mykiss)* in the United States, described the industry as mature and relatively stable. Rainbow trout constitute the overwhelming majority of trout species produced in commercial facilities, but other species, such as the Eastern brook trout (*Salvelinus fontinalis)* and European brown trout (*Salmon trutta),* are also produced in limited numbers. According to the 2005 Census of Aquaculture (NASS, 2006), the national trout industry consists of 410 farming operations located in 38 states. The major producing state is Idaho, with 45% of domestic production by value, followed by Washington, California, North Carolina, Pennsylvania, and Missouri. The majority of these operations are small, family-operated businesses, with average annual sales of about $193,000. The larger operations, which are only about 20% of the farms by number, account for over 85% of total sales (Hinshaw et al. 2004). This dichotomy in farm sizes exists within most states, with a few large companies or farms producing most of the fish in a respective area.

Rainbow trout, like salmon, grow best in flowing water. Historically and typically, this is supplied by tapping springs or streams and diverting the water flow through ponds or raceways (Figure 10.14). Like salmon, rainbow trout can also be grown in net pens, and because they will acclimate and grow well in saltwater, there has been a substantial increase in marine production of trout worldwide in recent years (Figure 10.15). Most of the recent growth in global trout production has been in saltwater, where the fish are grown to a size larger than is typical for fresh water. In Europe, these saltwater-grown fish are sold as "salmon trout," which reflects the fact that the flesh is red and sizes may be 2-4 kg. In the United States, such fish are sold as steelhead and are mostly imported from Chile, although some production of large trout occurs in fresh water in the states of Washington and North Carolina. Therefore, two quite distinct markets exist for rainbow trout nationally: one, for "portion size" fish - as are produced in most freshwater trout farms, and the other, for "large trout" - as are grown in net-pens.

Production of trout in the United Sates has lagged behind the rest of the world and remained relatively stable for the last 20 years (Figure 10.15). This reflects the fact that most of the best freshwater sources for raising these fish were identified and secured years ago, especially in Idaho. There are few, if any, sources of freshwater today which could be tapped to expand the industry using typical, flowing water raceway farming. In fact, trout farmers in some states are under pressure to cut production in response to demands for water elsewhere and/or diminishing flow levels from aquifers. A minor exception is the production of larger trout from net pens in freshwater in Washington and North Carolina, although here too opportunities are limited. Meanwhile, farming of trout in saltwater in both Washington and Maine has not been successful compared to Atlantic salmon farming and, in any case, opportunities to expand saltwater net-pen farming in these states are limited.

Figure 10.14. U.S. rainbow trout farms.

Figure 8.6 Some different systems in which Rainbow trout are grown

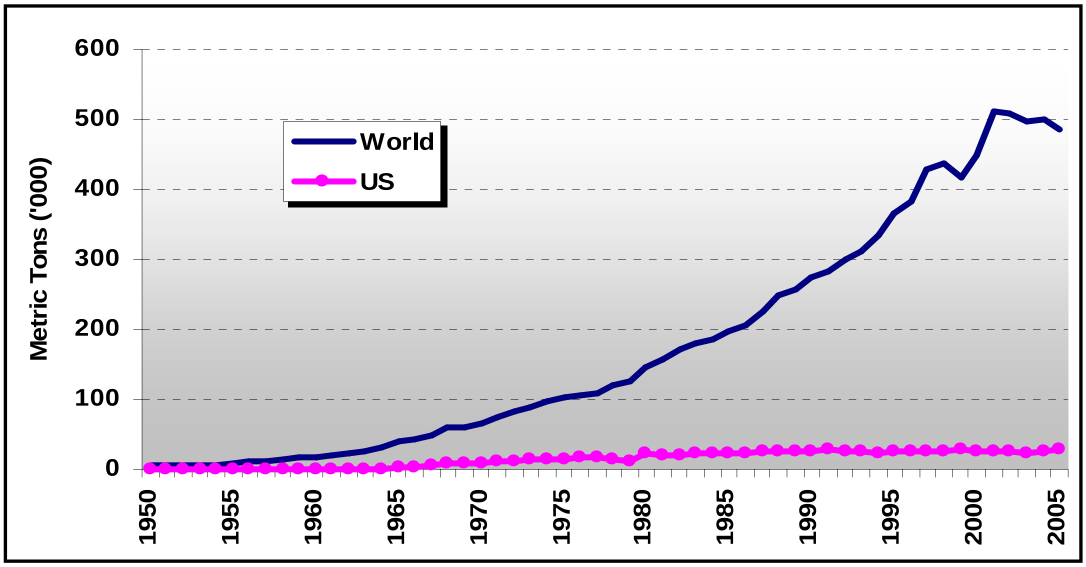
A tout farm using earthen production ponds (from Hinshaw et al. 2004)

Clear Springs Trout Farm in Idaho uses concrete raceways supplied by spring water

Columbia River Fish Farms in Washington State uses net pens in reservoir of the Columbia River.

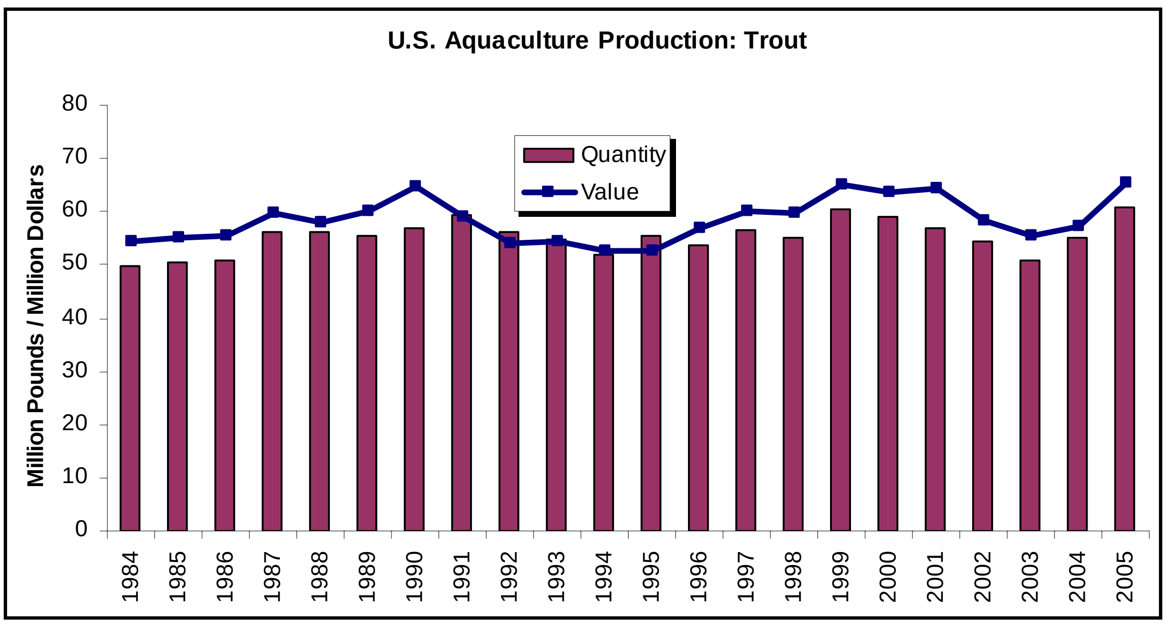
The outlook for U.S. trout farming is continued stability (Figure 10.16). Diminishing water supplies and pressure to reduce water consumption will most likely be countered by even more efficient farming, but the prospects for any possible expansion using traditional flowing water methods seem negligible. Production offshore in saltwater net-pens is feasible along the northeast and northwest coastlines of the country, and especially in the near-shore waters of Alaska, but development is unlikely at present.

Figure 10.15. World and U.S. production of rainbow trout.



Source: FAO, 2007

Figure 10.16. U.S. rainbow trout production.

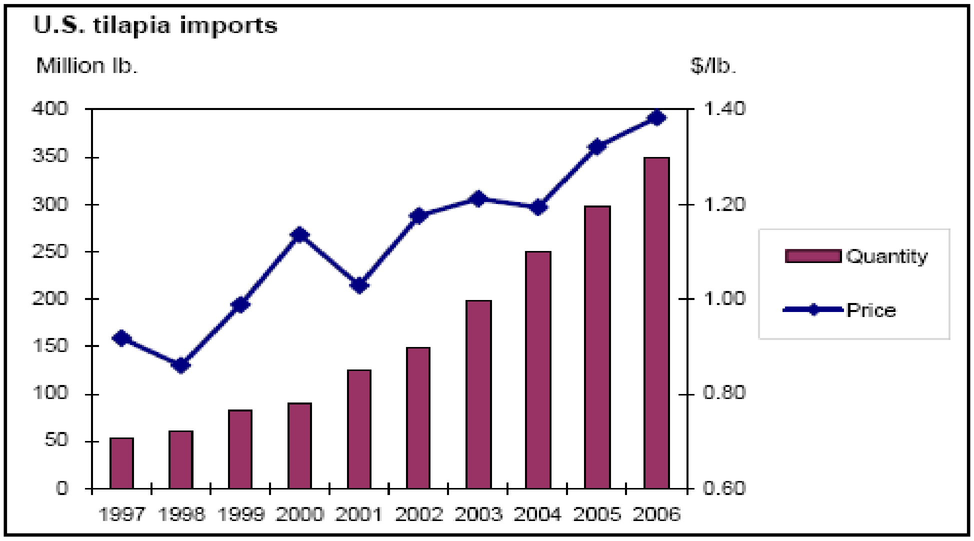


Source: NMFS, 1999, 2003, 2007

<u>*5. Tilapia and recirculation aquaculture systems (RAS).*</u>

A smaller but important part of American food fish aquaculture is the farming of tilapia. It is important for two reasons. First, tilapia has become a popular food fish in the United States in recent years with most supplies coming from overseas producers especially in Central and South America and Asia (Figure 10.17). Second, almost 8,000 mt of this tilapia is grown in the United States (Table 10.1) in recirculating aquaculture systems (RAS) where, by continuous recycling and reconditioning of the culture water, the temperature can be maintained at a level at which

Figure 10.17. Tilapia imports in the United States.



Source: *Aquaculture Outlook,* April 2007

a tropical fish like tilapia grows well. These fish are almost all sold live in areas where certain ethnic groups prefer to buy their fish in this way, and they are sold at premium prices compared to imported processed tilapia products

Control of water temperature in RAS at any level that the operator chooses means that this technology can be used, in principle, to grow any species of fish. Therefore RAS have numerous potential applications in aquaculture and are the subject of intense research. The key challenge is to be able to build and operate them at a cost that allows them to compete with other methods of aquaculture as described above. Higher costs in RAS result from the investment needed for water treatment and control equipment and the energy, biosecurity, and other costs of operation (Figure 10.21). Presently, RAS are most successful when used to grow high value products such as live tilapia, sturgeon for the production of caviar, and barramundi. They are also being used increasingly in hatcheries where controlling both temperature and microbial content of water makes them especially suitable for culturing the delicate early life stages of many species, including salmon. For the same reason, almost all public aquariums are RAS and the technology is also used in ornamental fish breeding.

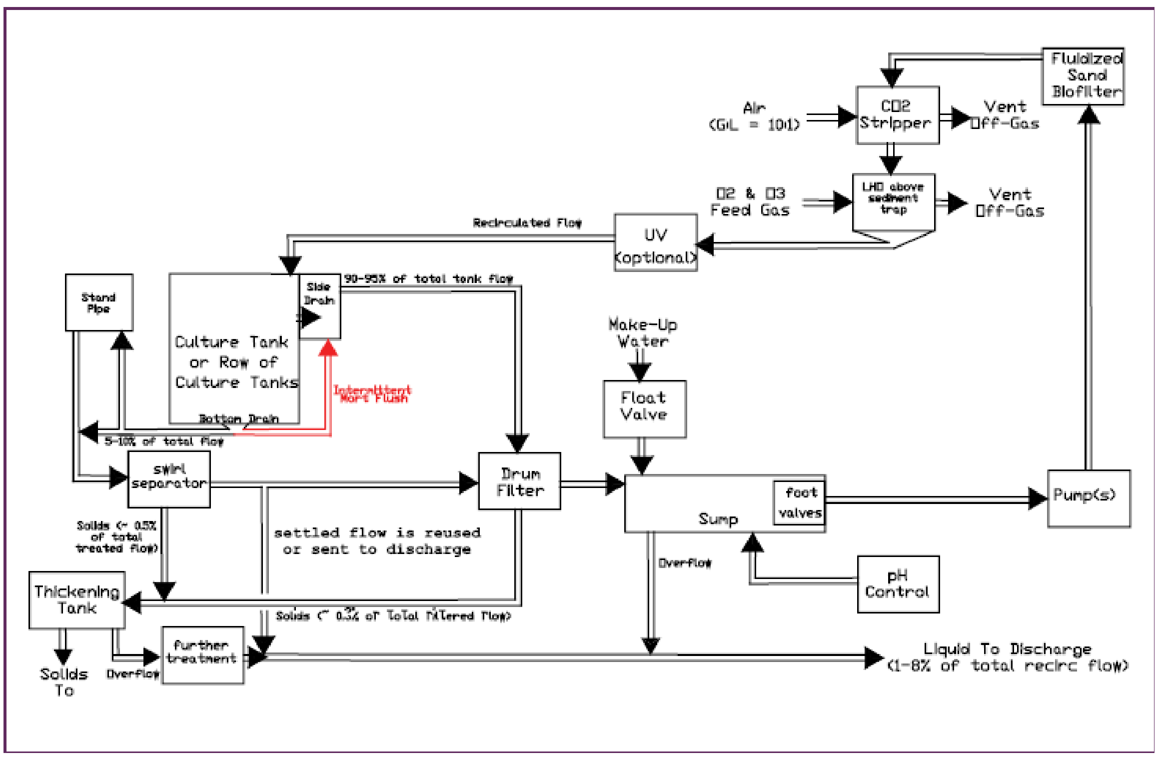
Another benefit of RAS is that they use and discharge much less water than other methods of aquaculture. Therefore, there is greater flexibility as to where they can be located because they are not so dependent on large natural water sources for their water supply and their waste water can be treated before discharge back into natural water bodies.

6. Public sector aquaculture

Hatchery-reared fingerlings and spat are released to enhance commercial and recreational catch or to restore threatened or endangered populations of fish and shellfish. Also, shellfish spat and marsh grasses are produced by public hatcheries or private companies for public programs to rebuild shellfish and marsh habitat. Statistics for the production of juveniles to support the recreational fishing industry are separated from the statistics for annual commercial

Figure 10.18 A Recirculating Aquaculture System (RAS) for Tilapia and Process Flow Diagram.

Figure 3. A RAS using a CycloBio Filter, Low Head Oxygenation (LHO) Unit and Stripping Columns. Water flow exiting the top of the fluidized-sand biofilter flows by gravity through a cascade stripping column, an LHO unit, and a UV irradiation unit before being piped by gravity to the culture tank. Photo courtesy of the Conservation Fund Freshwater Institute (Shepherdstown, WV).



Source Timmons and Ebeling 2006

aquaculture production in most state and federal fisheries and aquaculture reports. The most common species raised and stocked to support recreational fisheries are bluegill, catfish, largemouth and smallmouth bass, muskellunge, northern pike, salmon and trout, sauger and walleye, steelhead, striped bass, and sunfish (Nash, 1995). Hundreds of millions of juveniles are raised each year in over 75 hatcheries operated by the U.S. Fish and Wildlife Service's National Fish Hatchery System, more than 1,000 private hatcheries and hundreds of state hatcheries.

Production volumes for stocking from restoration and enhancement hatcheries for marine species are hard to pin down. Hatchery-based production of fingerlings has been or was conducted for many years to enhance or restore fisheries for striped bass on the East Coast and Gulf, for red fish in the Gulf, and white sea bass in California. However, data for yields directly attributable to released fish are not available (Drawbridge, 2006; Leber, 2006), except for salmon for which it is possible make an estimate of value, though not weight, by making certain assumptions.

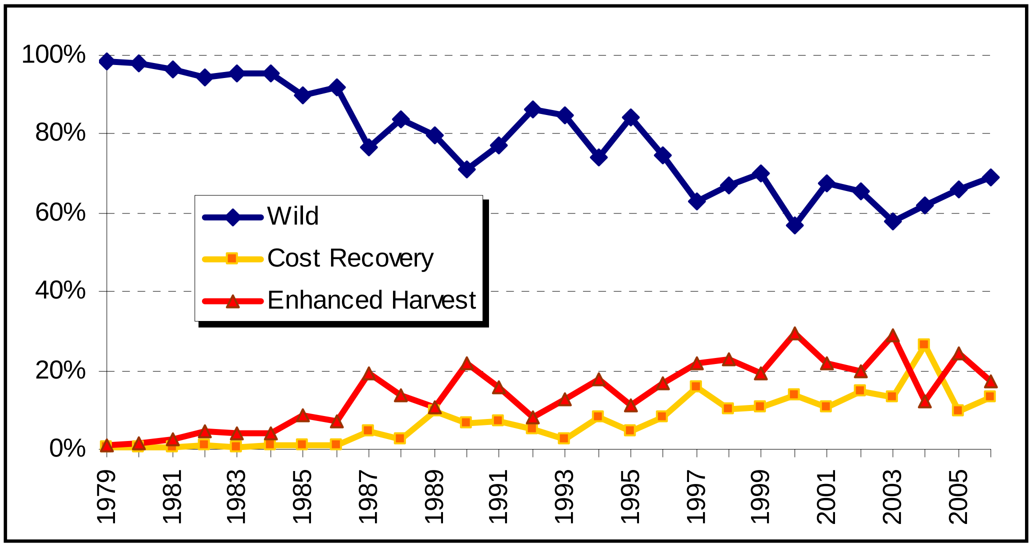
The numbers and values for releases and catches of hatchery-raised salmon on the West Coast and Alaska vary. Data for production from Pacific salmon enhancement hatcheries in Alaska (see Figure 10.19) have been summarized by White (2005) and McGee (undated). According to White,

> "*Over 1.5 billion eggs were collected by Alaskan hatchery operators in 2005. In addition, over 1.4 billion fish were released. An estimated 80 million salmon of hatchery origin returned. Of the 200 million salmon harvested in the commercial common property fishery, over 53 million or 27% of the harvest was contributed by ocean ranching by the Alaska salmon enhancement program. Enhanced salmon provided over $39 million or 14% of the preliminary value of the common property harvest. The ocean ranching program provides hundreds of Alaskans with seasonal and full time jobs. It is considered the largest agricultural industry in Alaska.*"

The fact that 27% of the harvest contributed only 14% of the value is because the vast majority of hatchery-reared salmon for stock enhancement are chum and pink salmon. These are the least valuable species but also the easiest to rear in a hatchery. However, the actual contribution of salmon hatcheries in Alaska may be higher than the number provided by White (2005). For example, Knapp et al (2007) included both cost recovery harvest and enhanced fish harvest as contribution of hatchery-based salmon farming to commercial harvest and estimated the total enhanced harvest represented 33.8% of the total commercial harvest in 2005, rather than 14% as stated by White.

In contrast, hatchery releases from federal, state, and tribal hatcheries in Washington, Oregon, and California are mostly of the higher-value salmon species such as Chinook and Coho salmon. Bartlett (2005) reported that almost 300 million salmon in total were released into Pacific Northwest waters in 2004 and that 4,640 tons of Chinook and 244 tons of Coho were caught in the commercial fisheries in the same year. Furthermore, he indicated that coastal and freshwater fisheries and the sport fisheries took another 3,699 tons of Chinook and 2,710 tons of Coho, assuming the same average weights as in the commercial fisheries.

Figure 10.19. Contribution of hatchery-reared salmon to the Alaskan fishery.



Source: ADFG, 1979-2005

The ex-vessel value of the non-Indian commercial ocean fishery for salmon in these three coastal states in 2004 was $29 million. Although a value for fish harvested in coastal and fresh waters and in sport fisheries is not provided, it is clear that this value is at least as large as that of the commercial fishery, if not more. Therefore, a reasonable approximation of aggregate weights and values from these hatchery-enhanced fisheries in Washington, Oregon, and California is 8,000 tons of Chinook salmon and 3,000 tons of Coho, yielding a total ex-vessel equivalent value of about $60 million suggesting that enhancement aquaculture is one of the country's major aquaculture activities.

For completeness, it must also be noted that there are hatcheries for enhancement and/or restoration of Atlantic salmon on the East Coast and for certain Pacific salmon species in the Great Lakes. However, none of these programs supports a commercial fishery; therefore, they do not contribute to the overall commercial value.

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